BORDER COMPETITION IN FIELD CROP EXPERIMENTS.

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April, 1928.

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INTRODUCTION.

During the past fifteen years agronomic research has uncovered a large number of hitherto hidden errors in field crop experimental work. Among these, the error introduced by border effect along uncropped pathways between plots is noteworthy. The outer rows of grain, having access to whatever moisture is available in the uncropped pathway, tend to grow and produce more abundantly than the others. Consequently yields from plots harvested in entirety , were unduly high. In order to eliminate this error various expedients have been adopted. Some investigators discard the pathways and grow the varieties in close proximity to each other, leaving a distance between the plots equal to that between the rows in the plots. This still leaves it necessary to trim the ends of the rows which usually adjoin a roadway. In other cases where paths remain between plots, two or more of the outside rows are discarded, the yield data being obtained from the remainder of the plot.

At the University of Alberta a combination of these methods has been adopted. Two types of plots are in use. For preliminary small-grain testing, plots consisting of three rows, twenty-seven links long and one link apart are laid down in series. The plots are one link apart and

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the first, and every ensuing tenth plot are seeded to a standard variety of the grain under test, e.g. Marquis in wheat tests and O. A. C. 21 in barley tests. These are known as check plots and their yields are used as an aid in interpreting differences in the yields of the replicates of other varieties or strains which may be due to such factors as soil heterogeneity. Pathways between ranges of plots are all seeded to winter wheat in order to protect the ends of the rows from border effect. At harvest time the two outer rows of each variety are discarded and the ends of the middle rows are trimmed off, leaving a row exactly one rod long from which the yields are taken.

For more advanced variety tests, hundredth acre plots, consisting of fourteen rows, one link apart are grown. The distance between the last row of one plot and the first row of the succeeding one is also one link. At harvest time the two outer rows on each side of the plot are discarded, the ends of the remaining rows trimmed off, and the yield determined from the remainder of the plot.

While the necessity for removing border rows adjoining pathways is self evident, there remains some question as to the necessity for growing the extra rows in cases where no paths intervene between the plots of different varieties. From a purely economic viewpoint, the discarding of two-thirds of the grain grown as in rod-row plots, seems

wasteful. In addition, three times as much land is used as is required for the actual test, or alternatively, the use of single rows would allow of three times as much replication, which, if it introduced no new errors, would ensure more reliable results. We are therefore faced with the question of what effect on the accuracy of experimental results would follow the change from the present three-row plot to the single-row system.

Before a decision on this point can be made it is necessary that the possible effect of one variety on the adjacent rows of other varieties be considered. While competition is an established fact in determining which plants shall survive in nature, its effects may be masked under the conditions which surround variety testing. If there proves to be any suspicion that one variety may affect its neighbour, the border rows must be continued. If not, the single-row system, with its obvious economies of time and space, should be used in preliminary testing, and yield should be taken from the larger plots without discarding border rows.

Investigations which will be discussed later seem to indicate that climatic conditions have a strong influence in determining presence or absence of competitive effects. It is obvious then that any change in our system at the University of Alberta can only be based on results obtained

under the conditions which exist here. For this reason the study of inter-varietal effects which follows was outlined in 1926.

REVIEW OF LITERATURE.

Grantham (1), working with ten varieties of wheat, obtained evidence of competition between plants of the same variety when a heavy rate of seeding was used. A decrease in tillering, length of spike and grain production occurred in all cases but most markedly in the beardless varieties. Kiesselbach (3) noted similar effects with wheat at heavy rates of seeding, except that there was no definite evidence to show that beardless varieties were the weaker competitors. He found in addition, distinct competitive effects between plants from large and small seeds of the same variety grown in the same row. When plants from different varieties grew in the same row competition also exercised some influence. Yields from alternate rows of light and heavy seeding when compared with the yields from the centre rows of similar alternating five-row plots , indicated that heavy seeding had a distinct advantage in the single rows.

Using the alternating single rows and alternating five-row plots for comparison, Kiesselbach (4) also obtained evidence of competition between different strains of the same variety of wheat and also between different varieties

in Nebraska. With oats and corn the proximity of unlike varieties resulted in differences in yield as a result of competition. Different rates of seeding showed competitive effects in corn seeded in hills forty-four inches apart. The relative competing ability of varieties of various grains fluctuated from year to year, from which fact Kiesselbach concluded that climatic conditions govern the extent of competition.

Love and Craig (7) in describing the conditions under which comparative tests of small grains are carried out at Cornell, state that their rod-row tests are seeded in single rows one foot apart. Care is taken to keep varieties and strains of similar agronomic characteristics together. By this means, they believe they prevent the error caused by competition from being large enough to upset the true relative order of yield. Love (8) in a later paper repeats this idea, and points out in addition that under some conditions shade may be a factor in giving one variety an advantage over another. Kiesselbach (5) however quotes an extreme instance of competition in which winter wheat seriously depressed the growth of adjacent rows of spring wheat. The spring wheat in this case was seeded south of the winter wheat and the rows ran from east to west. Kiesselbach explains this case as a direct result of the earlier-growing winter wheat removing moisture from some area of the spring-

wheat plot. Competition occurred at the Nebraska station equally as often and as seriously in rows seeded north and south as in those in the opposite direction. In replying to Love with regard to seeding like varieties together, Kiesselbach (5) raises the valid objection that the experimenter frequently must grow varieties about which he has no previous information. This makes the system of grouping according to length of growing season, height, etc, a hazardous proceeding. In conclusion Kiesselbach notes that, under Nebraska conditions at least, no correlation has been established between yield and competing quality.

In a later paper Kiesselbach (6) discusses the effect of competition on corn yields. He shows that the established rate of seeding for corn is sufficient to provide for normal yield but that it does not allow of full development of every plant. The rate of seeding results in a keen competition for moisture, and possibly nutrients and light, among neighbouring plants. Data are advanced to show that competition is influenced by the intensity of these limiting factors for growth and the degree of difference of the crops concerned. The fact that disease may thin out the stand of one of the varieties concerned must also be taken into account as, in addition to intervarietal competition, there is set up a series of conditions similar to those found where different rates of seeding are used in adjoining plots. Kiesselbach concludes

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by suggesting the following practices in laying out preliminary tests of small grains.

1. Grouping of similar sorts.
2. Growing border rows which may be discarded at harvest time.
3. Planting a small surplus of seed and thinning out to the required stand after growth is well under way.
4. Basing yields only on plots containing a full stand.
5.. Determining if possible the optimum planting rate for each variety and using that in each case.

Stadler (11) investigated the effect of competition under Missouri conditions by growing alternate single rows and alternate five-row plots for comparison, after the plan of Kiesselbach. He obtained data showing marked competition between rye and wheat and also between varieties of wheat, oats, and barley. Less marked, but still significant, data on competition were secured from alternate rows of strains of the same variety. Competitive effects were noted no matter in which direction the rows were planted. The agronomic features most closely correlated with competing ability in wheat were yielding ability and earliness. In one year there was some correlation between height and competing ability in wheat. In oats competing ability and yield were less closely correlated although there was a correlation between earliness and competing power. No significant

[illegible]

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correlations were obtained with barley.

Stadler believes that a system of replicated three-row plots (i.e. protected single rows) would be more satisfactory from the point of view of accuracy and economy combined, than an equal total number of rows in five-row plots. He feels sure that under Missouri conditions the single-row system of testing would be inaccurate, on account of competition.

In Ohio, Stringfield (12) found only occasional disturbances in relative yield as a result of competition. No correlation existed between any agronomic qualities and ability to compete, nor did the direction of the rows seem to have any marked effect. He suggests that the use of the single-row system under Ohio conditions would be quite satisfactory provided varieties of similar habit of growth and time of maturity are grouped.

Olson (10), in commenting on Stringfield's work, states that no competition was found between a late, tall-growing corn variety and an early, low-growing one. These were grown in rows running north and south at the Montana station.

While the work of Williams at Aberystwith, Wales(14) does not deal with grain, it has a bearing on competition in general. He reports that a late-flowering clover is at a decided disadvantage in yield when grown with, or adjacent to, an early-flowering variety. This difference is marked not only in the hay yield but in the aftermath and is attributed

by Williams to shade. Since bulk weights were affected in this case it might be possible that in certain cases where the grain yields do not show the effect of competition the weight of grain plus the straw might give more satisfactory evidence.

The work discussed so far deals entirely with cases wherein one variety benefits at the expense of another. Since cases occur in nature where plants of widely differing types seem to stimulate the growth of one another there may be a possibility that such an effect can occur with grains. Zavitz (15) reports a long series of experiments indicating that greater yields are obtained from oats and barley grown in combination than from similar acreages of these crops grown alone. The same is true with other crops but to a less degree. So far as Zavitz was able to ascertain, no beneficial effects were produced when varieties of the same kind of grain were grown in combination.

Karraker (2) found that bluegrass yields were increased when sweet clover was grown with the crop. While Lyon and Bizzel (9) obtained yields from red clover and oats in combination which were greater than the yields from similar areas of these crops grown alone. Thatcher (13) quotes classic cases of plants of widely different species having beneficial effects upon one another.

Should such effects occur as the result of two varieties of grains being grown in adjacent rows, the discrepancy in the order of the yields obtained, might not be so wide as in cases of straight competition. Nevertheless an error would be introduced which would certainly affect the accuracy of all data on yield for any series of grains.

MATERIALS AND METHODS.

When the investigation commenced in 1926, there were being grown in the rod-row plots at the University of Alberta a large number of varieties and strains of wheat and barley. In some cases these strains were merely being multiplied for seed and were growing in single plots. However there were 53 strains and varieties of wheat and 23 of barley under test for yield and other agronomic features, and these were being grown in quadruplicate plots. It was therefore decided that these should form the basis of a study on the effect of the border rows of one variety on those of its neighbour.

All of the wheat plots were grown in one field and all of the barleys in another, the rows in both cases running north and south. The plots consisted of three rows, 27 links long and 1 link apart. The distance from plot to plot was also 1 link. These plots were laid down in ranges starting from the east in each case. In order to remove any possible border effect, the paths between the ranges were seeded to

winter wheat and before harvest 1 link was removed from the end of each row. The remaining 25 links of each row was harvested as one sheaf.

To each sheaf was attached a label on which was written the number of the plot and a letter A. B. or C, to designate whether the sheaf in question represented an east, middle or west row. Thus the sheaf bearing the number 46C came from the row between 46B and 47A, and so on.

The sheaves were harvested separately and the grain product weighed in ounces, the weight being marked in the records opposite the plot and row number.

Since the first and every ensuing tenth plot were checks, seeded in the case of wheat to Marquis and in the case of barley to O. A. C. 21A, all plots whose number ended in 1 belonged to these varieties. All other varieties and strains were seeded in the same consecutive order in each of the four replications except where the regularly placed checks intervened. Wherever a check occurred, only three plots of the strains adjoining could be used in the calculations, as the competing effects of checks and strains would not necessarily be the same. In other cases data from four plots were used.

In 1926, there were also under test in the larger variety plots, 14 varieties. These were seeded in plots of fourteen

rows one link apart, the rows being 100 links long and running east and west. At harvest the rows were trimmed to 97.5 links and the two border rows on each side removed separately. In addition to this, the 7th and 8th rows were also harvested together. The remaining eight rows were harvested in bulk. To the sheaves removed from the plot were attached labels bearing the plot number and in addition a number showing to which row the sheaf belonged. Yield data were kept in the same way as in the rod-rows.

In 1927, both wheat and barley quadruplicate rod rows were grown. The barley was badly lodged by a heavy rain accompanied by high winds in July, and did not recover. As an effect of the lodging may have overshadowed the effect of competition it was decided to leave these rows out of consideration. The wheat rod rows did not lodge to the same extent, and many of those that lodged recovered within a few days. Thus the 50 strains and varieties of wheat in the test were used in the investigation.

In the 1927 variety plots of the larger size there were 17 varieties in quadruplicate, in addition to 14 check plots of Marquis wheat. Data from this experiment were collected as in 1926, but in addition the bulk weights of the 1st, 2nd, 7th, 8th, 13th, and 14th rows were determined, and the seed weights from rows 7 and 8 were taken separately.

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RESULTS.

The data from the 1926 rod rows were first considered. Since under effectual competition one border row should benefit at the expense of the adjoining row of the next variety it would be expected that an increased yield for the 'C' row of one plot would be accompanied by an increased yield in the 'A' row of the following plot. This should appear when the yields are set down in in order as follows,

Variety	35			36			37		
Row	A.	B.	C.	A.	B.	C.	A.	B.	C.
Yield(ozs)	12.5	12.75	13.25	12,5	12.0	13.0	10.75	11.25	10.5.

Since both the 'C' row of plot 35 and the 'A' row of plot 36 are greater than their respective 'B' rows there is no reason to expect that competition occurs between plots 35 and 36. However in 36, 'C' is greater than 'B' and in 37 'A' is less than 'B'. Such a condition would be expected under competitive conditions.

In discussing data similar to the above Stringfield (12) suggests a method which might well be discussed at this point. He states that under effectual competition the difference between the border-row yields should definitely exceed the difference between the certre-row yields of the same plots. He illustrates with the following example.

Variety	A			B		
Row	A	B	C	A	B	C
Yield	100	100	110	80	90	90

Border row difference = 110-80 = 30

Centre row difference = 100-90 = 10

Border row difference - centre row difference = +20.

The plus sign in the final result, according to Stringfield, represents competition.

When this method is applied to the data from varieties 35, 36 and 37, the high-yielding variety increases in the border rows, at the expense of the adjacent row of the low-yielding variety.

Examination of the following actual case from 1926 wheat rod-row plots, in which the lower yielder apparently competes advantageously , discloses a weakness in the method used by Stringfield.

Variety	25			26		
Row	A	B	C	A	B	C
Yield(oz)	10.0	10.0	11.5	10.75	12.0	10.0

Border row difference = 11.5-10.75 = 0.75

Centre row difference = 12.0-10.0 = 2.00

Border row difference - centre row difference = -1.25

The border-row difference in this case is less than the centre-row difference, yet the actual data suggest competition.

A supposed third case discloses another point which might cause inaccurate results by the use of this method.

Variety	A			B		
Row	A	B	C	A	B	C
Yield	100	100	115	100	90	90

Border row difference = 115-100 = 15

Centre row difference = 100- 90 = 10

Border row difference - centre row difference = + 5.

In this case the border row difference exceeds the centre row difference but the data indicate that both border rows are unduly high in yield. This is certainly not a clear case of competition as the disturbance in yield may be due to soil factors, mutual stimulation or some other agency.

These cases suggest that this method may be considered applicable only if the high-yielding variety is the strong competitor. Since we have no evidence to support this idea, we must use another method of detecting the presence of competition.

It is evident that in a case where a strong and a weak competitor adjoin one another the outer rows of the strong and the outer rows of the weak competitor should be high and low respectively. This should always be the case where these varieties come together. An examination of the replicates of the three varieties already mentioned may now be undertaken. The replicate yields in ounces are given in table I.

TableI.

Yields in ounces of Rows of three Adjacent Varieties.

Variety	35			36			37		
Row	A	B	C	A	B	C	A	B	C
1st Replicate	12.50	12.75	13.25	12.50	12.00	13.00	10.75	1125	10.50
2nd "	14.75	14.75	11.25	12.00	12.00	13.25	8.50	9.75	12.50
3rd "	12.50	13.50	11.50	10.75	10.25	10.75	10.00	10.00	11.50
4th "	14.75	14.00	11.00	14.00	16.25	16.25	10.25	12.00	11.25

It will be observed that the 'C' rows of 35 are respectively greater, less, less, and less than the 'B' rows. While the 'A' rows of 36 are respectively greater, equal to, greater and less than the 'B' rows. There is no evidence of a significant increase or decrease of yield in either case. In comparing the 'C' rows of 36, we find that three of them are greater than, and the fourth equal to the 'B' row. Three of the 'A' rows of 37 are less than, and a fourth equal to the corresponding 'B' row. This may be some indication of competitive effect.

In the analysis of data such as these, Student's method was used. This method consists of determining the mean difference for any number of pairs, e,g, 'B' and 'C' rows. The standard deviation of the differences is calculated by the formula

$$S.\ D. = \sqrt{\frac{\Sigma d^2}{n}}$$

and the mean difference divided by the standard deviation of the differences to give Z.

$$Z = \frac{\text{mean difference}}{\text{Standard deviation of the differences}}$$

The odds for Z for any number of paired observations are given in Student's Table. These odds are usually asumed to express the probability of the difference being a real one.

The value of this method lies in the fact that it takes into consideration both the amount and the direction of the

[illegible] that the 'C' rows of [illegible] respectively greater, [illegible], less, and less than the 'B' rows. While the 'C' rows of 36 are respectively greater, equal to, greater and less than the 'B' rows. There is no evidence of a significant increase or decrease of yield in either case. In comparing the 'C' rows of 36, we find that three of them are greater than, and the fourth equal to the 'B' rows. Three of the 'A' rows of 37 are less than, and a fourth equal to the corresponding 'B' row. This may be some indication of competitive effect.

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$$\sqrt{\frac{\Sigma d^2}{n}} \; [illegible]$$

and the mean difference divided by the standard deviation of the differences is [illegible].

$$[illegible]$$

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The value of this method lies in the fact that it takes into consideration both the amount and the direction of the

differences. It has to be used with care in some circumstances however, as will be shown later. In table II the differences between the B and C rows of variety 36 are calculated according to Student's method.

Table II.

Yields of Rows B and C, Variety 36.
Probability of the difference calculated according to Student's method.

	Yields per Row. B oz.	C oz.	Gain of C. over B. oz.	D.	D^2
1st replicate	12.00	13.00	1.0	0.25	0.0625
2nd "	12.00	13.50	1.5	0.75	0.5625
3rd "	10.25	10.75	0.5	0.25	0.0625
4th "	16.25	16.25	0.0	0.75	0.5625
			3.0		1.25

Mean Gain = 0.75

$$\text{Standard Deviation} = \sqrt{\frac{1.25}{4}} = 0.559$$

$$Z \ \frac{0.750}{0.559} = 1.34$$

Odds = 18:1

When the method was applied to the wheat rod-row data obtained in 1926, it was found that in only 17 sets of replicates out of 52 where plots were adjoining one another were the odds over 20:1 that the 'A' or 'C' row was significantly

greater or less than the 'B' row and in only one case were the differences in an upward direction, accompanied by a decrease in the adjoining border. This case is shown in table III.

Table III.

Yields of Rows of Adjoining Replicates in Ounces.

Variety	38			39		
Row	A	B	C	A	B	C
1st Replicate	10.50	10.50	9.25	12.50	11.75	10.00
2nd "	10.25	16.25	9.00	8.00	7.25	12.25
3rd "	10.75	12.00	10.00	11.75	11.50	12.25
4th "	10.25	12.00	11.25	12.25	11.00	12.75.

The odds that the B and C difference is significant in 38 are 131:1, and the odds for the A and B difference in 39 over 1200:1. It will be noticed that the differences are very small, particularly in the latter case. The fact that they are consistent, however, leads to high odds when this method is used. Because of this the odds have been used only to pick out cases where there may be a suspicion that competition exists, and the actual data presented to confirm or reject the case.

In the barley rod-rows for 1926, out of 22 sets of adjoining replicates, odds of over 20:1 occurred on four occasions omly and on no occasion were they together. Thus there was no evidence of competition in so far as the adjoining

border rows of the barley varieties under test were concerned.

The larger wheat variety plots for 1926 were next considered. Since the first and second and thirteenth and fourteenth rows were harvested separately it is possible to deal with these in the same manner as the rod rows. The thirteenth row being the inner border may be considered as a B row as may the second row of the next consecutive plot while the fourteenth row of one plot and the first row of the following plot represent the same conditions as the C and A rows in the rod-row series. Thus an increase of row 14 over row 13 in plot 1 followed by a decrease from row 2 to row 1 in plot 2 might indicate competition.

When the odds for the 1st and 2nd and 13th and 14th row differences had been worked out for all plots, it was found that high odds were obtained for the Garnet and Mindum plots only. The 14th row in each of the Mindum plots produced less grain than the 13th. In addition to this, the first row of Garnet in each case yielded more than the second. The odds that the Mindum border rows was significant were 22.7:1 and, that the Garnet difference was significant 832:1. The yields for all border rows of these plots are given in table IV. The heavy yields of the first rows of the Garnet replicates are quite noticeable, the highest-yielding row in each replicate being that one adjoining the Mindum plot. While the

difference between the Mindum border next Garnet and the other Mindum rows is not so pronounced, there is a decrease from the yield of row 13 in each case.

Table IV.

Variety	Mindum.				Garnet.			
Row	1	2	13	14	1	2	13	14
1st Replicate	23.00	27.25	26.00	19.25	46.25	35.00	38.00	36.25
2nd "	23.25	29.75	35.25	32.00	55.50	46.75	45.50	42.25
3rd "	30.75	29.25	46.50	27.75	59.75	47.00	45.00	46.25
4th "	34.00	42.50	29.75	23.50	55.00	46.75	40.25	?

N.B. Row 14, Replicate 4, of Garnet was dammaged by birds.

This case gives more reason for an assumption that competition may exist than any of those quoted above. Garnet is a very early and Mindum a late variety. In addition, as will be seen from row yields Garnet is a heavier yielder. It might be possible then, by the growing of a larger number of replicates of these varieties adjoining one another, to determine with some degree of accuracy whether this apparent competitive effect is always present. It should also be possible from such an experiment to obtain data on which a determination of the relative correlations of yield, earliness, and competing quality could be based. Such a test would of necessity cover a number of seasons, as climatic conditions could

seriously affect any data obtained, because of the wide differences in the maturity periods of these varieties.

In view of the fact that the summer of 1926 was marked by one long spell of dry weather about heading time, it is surprising to find that there are so few cases which would allow of a justifiable suspicion of the presence of competition. Competition for moisture would be liable to result in marked differences between the strong and weak competitors, but there were few and small differences in that season.

The summer of 1927 was a very favourable crop season from the standpoint of moisture supply. Consequently competition for moisture would not be so keen and more reliance could be placed upon evidences of competition for that season. Since the barley was badly lodged, and, as noted before, discarded for that reason, the only data available are for the wheat rod-rows and the variety plots.

In the rod-row plots for 1927, 18 cases out of a total of 100 occurred where odds of over 20:1 were obtained to show that the differences between centre and border rows were not due to chance alone. In two cases only, were the plots for which such odds were obtained paired, and in each case one variety had an increased yield in the border row while its neighbour had a decreased yield. These cases are presented below.

Case I, Yields in Ounces per Row.

Variety	19			20		
Row	A	B	C	A	B	C
1st Replicate	14.50	18.75	19.00	13.75	16.50	16.00
2nd "	12.75	11.75	13.00	11.50	14.50	13.00
3rd "	14.00	12.75	16.50	15.00	17.25	14.50
4th "	12.50	7.25	9.50	9.00	12.75	10.25.

In the case of variety 19, there is a consistent increase in the yield of the 'C' as compared with the 'B' rows. The increases are not as regular as are the decreases in the 'A' row of variety 20, but there is apparently some ground for the belief that competition may have caused the differences.

Case II, Yields in Ounces per Row.

Variety	49			50		
Row	A	B	C	A	B	C
1st Replicate	6.50	4.75	9.50	13.00	17.75	30.25
2nd "	6.25	5.50	11.75	10.00	13.75	20.00
3rd "	3.50	2.50	4.25	11.50	13.50	44.00
4th "	8.25	9.50	12.00	15.75	17.50	30.50.

In this case the unduly high yields of row 'C' variety 49 in proportion to the yields of the 'B' row are noteworthy. The depression in the 'A' row of variety 50 is also marked. Before placing too much stress on the value of these figures it is necessary to consider the 'C' rows of variety 50.

In row 'C' variety 50, it will be noticed that all of the yields are exceptionally high. This variety was the last in the series and consequently should have been adjacent to a check plot of Marquis in each case. However in the spring of 1927, it was expected that another strain was to be planted. The plots for this strain were left vacant for a week and finally seeded to winter wheat. Thus this variety was grow- adjacent to a plot of winter wheat seeded a week later. The spring wheat of variety 50 had emerged when the winter wheat was planted and as a result had an advantage throughout the growing season. This accounts for the abnormally high yields of row C in variety 50.

Since the prescence of the late-seeded winter wheat had the effect of unduly raising the yield of the 'C' row, it is reasonable to suppose that this effect could be carried into the 'B' row. The 'B' row yields are not high but it would not be wise to assume that they represent the correct yield for the variety. It is therefore possible that the 'A' and 'B'-row difference may not be as significant as the yield data would seem to indicate.

From the field experimental viewpoint, the high yield of row 'C' has considerable importance. It is occasionally necessary to carry on experiments to determine the most suitable date of seeding for various crops. In such experiments replicated series of plots are seeded down at the

desired intervals of time. Since the late seeding gave the adjoining plot of variety 50 an advantage, it is obvious that in date-of-seeding experiments, border rows should always be grown and discarded before the yields are taken.

When the data from the larger variety plots of 1927 were calculated by Students method for the odds of the significance of the differences of the outer two rows, four pairs of adjoining border rows seemed worthy of further consideration. It will be remembered that the total weight of grain and straw was taken in each case in 1927.

The data from the replicate plots which produced interesting results in this season have been contracted and simplified as far as possible. The method used in this case was to consider the weight of row 2 and row 13 of each as 100; the neighbouring rows (1 and 14) of the same plot are then expressed as percentages of these inner rows and the average of four replicates shown. Thus a case where two varieties compete strongly should show the border row of one variety as well over 100 and the border row of its neighbour as less than 100. Both bulk and seed weights have been tested in this way and in addition the odds of the difference according to Students method are given. The varieties whose border rows adjoin are paired in table V. The percentage relations of the contiguous borders show that there is no competitive effect in so far as bulk weights are concerned in any of the

first three cases. In each case the adjoining border rows increase in yield together. In two cases the seed weights show the same tendency while in the third a distinct increase in one outer row is accompanied by a very small decrease in its neighbour.

Table V.

Bulk and Seed Weights of outer Rows of Adjacent Varieties stated as Percentage of inner Rows, together with Odds According to Student's Method.

Adjacent Varieties	Bulk weight and Seed weight of outer row stated as percentage of inner row of same series.		Odds according to Students method.	
	Bulk weight.	Seed weight.	Bulk	Seed
Renfrew	115.9	116.2	Infinite	83 :1
Red Bobs 222	102.2	108.9	1.3:1	2.3:1
Red Bobs 222	102.8	104.9	12.2 :1	11 :1
Red Fife	111.1	127.2	Infinite	over 3000 :1
11-0-224	105.9	98.1	8.6:1	1.6:1
11-0-307	117.8	124.6	102 :1	10.9:1
Reward	87.5	94.5	34 :1	10 :1
Vermilion	111.0	112.4	83 :1	very small.

In the fourth case, that of Vermilion and Reward, both bulk and seed-weight figures seem to show what may be an effect of competition. The odds in this case indicate that there is some justification for assuming competitive effect in so far as the bulk-weight is concerned, but none in the seed-weights. The odds in the case of Vermilion seed-weight are very small as a result of a large variation in both size and direction of the differences, one outer row being slightly lighter than its inner row.

It will be noticed that when Red Fife and Renfrew adjoin Red Bobs 222 the odds for the significance of the increased bulk-weight of border rows reach infinity. This brings up a point already referred to in connection with Student's method. In the case of these varieties the bulk weight of the outer row of each replicate exceeded that of the inner row by the same amount. Hence the high odds. The sheaf weights were taken to the nearest quarter pound. A finer measurement would have shown differences in the weights and the odds would have been less than shown in the table, although they would still have been quite high.

We cannot conclude from such data that competition is a definite factor in changing the yields of border rows. However there are some interesting points in connection with this table. Renfrew and Red Fife are two late-maturing varieties and Red Bobs 222 is early. Since the late varieties

have significant differences in their outer rows, there is a possibility that such increased yields, while not due to competition, may nevertheless be the result of the proximity of the early variety. In the ripenung season the early variety may have ceased to draw heavily on soil moisture when the other varieties are still able to use it. This might account for the differences. In any event such differences would certainly cause misleading results should single-row tests of these varieties be grown.

It should be pointed out here in support of the contention that single-row results would be inaccurate, that the yields of the seventh and eighth rows of both the Red Fife and Renfrew varieties do not vary to any extent from the yields of the second and thirteenth rows, which are used as the standard of comparison in this table. This can be seen if the row yields of the Renfrew replicates are considered. The Red Bobs 222 plots followed the Renfrew plots in each case so that row 14 of the Renfrew replicates was always next to row 1 of a Red Bobs 222. plot. The row yields of Renfrew are given in table VI.

While the weights used in taking the bulk data have been criticised, it may be worth while to consider the bulk weights of this series also. It will be observed that there is a distinct tendency for the outer rows to furnish the heavy weights. Table VII gives the bulk weight of the rows of Renfrew wheat from the 1927 variety plots.

[illegible]
[illegible] of the two varieties. In [illegible] the [illegible] seemed to [illegible] heavily on soil [illegible] than the other varieties are still able to use it. This might account for the differences. In any event such differences would certainly cause misleading results should single-row tests of these varieties be grown.

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Table VI.

Yield in Ounces of Rows of Renfrew Wheat.

Row No.	1	2	7	8	13	14
1st Replicate	62.50	54.75	48.75	48.75	45.50	54.25
2nd "	52.00	51.75	55.00	55.75	50.25	62.00
3rd "	64.50	56.50	59.75	52.25	54.75	64.50
4th "	56.75	45.25	46.00	44.75	42.25	48.00

Table VII.

Bulk Weights in lbs. of Rows of Renfrew Wheat.

Row No.	1	2	7	8	13	14
1st Replicate	12.00	10.25	10.50	10.00	10.00	11.50
2nd "	11.50	10.00	10.75	10.25	9.50	11.00
3rd "	12.50	10.50	10.75	10.25	9.75	11.25
4th "	11.50	9.50	9.50	9.50	8.50	10.00.

The cases in which adjacent outer rows increase in yield together seem to suggest some form of mutual stimulation. However, as we have already pointed out, available moisture supply and length of growing season may be the cause of this increased yield, and no decision can be made on this point

from the data at present available.

In the discussion so far no reference has been made to the check plots. Since these plots are seeded at regular intervals throughout the experiment, the variety used as a check does not always come into contact with the same variety. Therefore if we assume for the time being that competition does exist, these check plots come into contact with a wide range of competitors, some of which may compete strongly and others not at all. The effect of this should be a more marked variation in the border-row yields than in the middle-row yields of these checks. In order to measure this variation the standard deviations for the middle rows and for the east and west rows were determined. The standard deviation for each set of check plots used, was calculated according to the formula

$$\text{Standard Deviation} = \sqrt{\frac{\Sigma d^2}{n}}$$

and is given in table VIII. The upper and lower figures given for the outer rows represent the east and west border rows respectively. For the purpose of computing the standard deviations of the variety-plot rows the inner row was considered in the same light as the middle row of a rod-row plot. No large differences occur in the mean yields, and the standard deviations, although they tend to show more variability in the outside rows, do not furnish conclusive evidence of competition.

		No. of check plots.	Mean Yields.		Standard Deviation.	
			Inner rows.	Outer rows.	Inner rows.	Outer rows.
1926	Rod rows Wheat	25	11.2 ± 0.19	10.5 ± 0.21	1.52 ± 0.14	1.69 ± 0.16
				13.6 ± 0.46		3.53 ± 0.32
	Rod rows Barley	14	16.7 ± 0.30	16.2 ± 0.35	1;70 ± 0.21	1.93 ± 0.25
				16.3 ± 0.33		1.85 ± 0.23
	Variety plots Wheat	11	22.9 ± 0.48	21.3 ± 0.67	3.25 ± 0.36	4.26 ± 0.50
1927	Rod row Wheat	25	13.5 ± 0.32	13.5 ± 0.47	2.33 ± 0.23	3.47 ± 0.35
				12.9 ± 0.31		2.19 ± 0.22
	Variety plots Wheat	14	22.9 ± 0.48	21.3 ± 0.67	3.25 ± 0.36	4.26 ± 0.50

DISCUSSION.

Before concluding the consideration of the results obtained during the past two years, it may be well to discuss some of the main features of the investigation a little farther. The general trend of the results so far obtained does not warrant the assumption that competition, as it is generally understood, is an active agent in disturbing row yields at the University of Alberta. However there is evidence to show that the adjoining border rows of different varieties show undue fluctuation. This fluctuation would be sufficient to introduce an appreciable error into yield data, if this were calculated from a single row growing between two other varieties. Thus, while the investigation has not established the fact that competition is present, the results warrant the continued use of the three-row plot and the discarding of the outer rows in the interests of accuracy. This would apply for the ordinary purposes of variety testing as well as for the dates-of-seeding experiments.

Some of the data obtained would doubtless be more significant if a higher number of replicates had been used. However since the investigation was originally planned to be carried on in plots used for yield testing work, this could not be done. The general layout of the tests is liable to some criticism from this point of view. Another difficulty

which arises in connection with the data obtained was illustrated in the case of the variety which adjoined the winter wheat. With only three rows per plot in an investigation of this kind we are forced to use the middle row as the standard of yield for that particular plot. There is no evidence to show that the middle row may not be affected by competition as well as the outer row. If this occurred the difference between the middle and border rows would not be so evident as both rows would probably be affected in the same way although possibly not to the same degree. This point would bear further investigation.

For the purpose of determining whether or not the middle row of a three-row plot is likely to be affected, an experiment such a s the following might be laid out. Two varieties A and B could be taken and seeded in rows in the following order:

```
A A A A A B A A B B A B B B B B.  If this were replicated
    5     1      2  1     5
```

sufficiently, reliable information could be obtained on the following points:

1. The yielding capacity of 'A' when entirely surrounded by 'A' rows.
2. The yielding capacity of 'A' when it is planted between two pairs of 'B' rows.
3. The yielding capacity of 'A' when growing between an 'A' and a 'B' row.

4. The yielding capacity of 'A when it has an 'A on either side of it, one of which rows is adjoined to a 'B' row. Similar data could be obtained for 'B. Such data while not directly applicable to field experimental conditions might at least show the cumulative effect of a varying number of rows of one variety upon the yield of the other.

Two similar series could be laid out, the rows in one case running north and south, and in the other east and west. This would allow of comparisons in order to determine the effect of the shading of one variety by another. The collection of data on height and rate of growth in addition to the usual agronomic notes taken in field tests would supply material for a further study of correlations which might reveal further means of overcoming competitive effect.

SUMMARY.

1. A study was made of the inner and outer rows of rod-row and hundredth-acre plots of wheat and barley in 1926 and of wheat in 1927, in order to determine whether or not competition with adjoining plots affected the yields of outer rows.
2. The data obtained do not support strongly the assumption that competition as generally defined is an active agent in causing fluctuations in row yields.

3. Some of the data show that where adjacent plots are seeded at different times, the outer rows of early seeded plots have a decided advantage in yield.
4. Despite the fact that no highly significant data were obtained to support the competition hypothesis, the greater fluctuations in the yields of border rows, prove that it would be inadvisable to discard the present three-row plot system.

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